CHAPTER 4

Safety of Meat and Poultry

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4.1 DESCRIPTION AND ORIGIN OF MEAT AND POULTRY

Meat being a rich nutrient matrix has been a first-choice food for people all over the world as a source of animal protein. Meat is a muscular tissue consisting of skeletal muscles, connective tissue, fat, and small amounts of smooth muscles like veins and arteries. Skeletal muscles are in turn made up of muscle fibers, which consist of rod-shaped myofibrils. Myofibrils and connective tissues are the main structural components of muscles. The animal muscle is typically composed of 60–80% water, 18–20% proteins, 0.5–19% lipids, 1–1.5% minerals, and a trace of carbohydrate (Jimenez-Colmenero et al., 2010). Lipids in fat cells contribute to the flavor and juiciness of meat. Fats exist in three ways: in marbling, as deposits between bundles of muscle fibers; as intermuscular fat; and as subcutaneous fat on the surfaces of muscles. High protein content is one of the most important characteristics of meat, which plays an important role in the human diet. It is a source of essential amino acids such as lysine, leucine, threonine, tryptophan, and methionine (Varnam & Sutherland, 1995).

Historical evidence suggests that meat constituted a substantial proportion of the diet for early humans. By at least 2.6 million years ago, there was a remarkable expansion in the diet when some hominids began incorporating meat and marrow from small to very large animals into their diet (Pobiner, 2013). Early humans hunted animals for meat; the earliest evidence for hunting dates back to 500,000 years ago (Wilkins, Schoville, Brown, & Chazan, 2012). Finally, humans started domesticating animals, first involving loose contacts (Zeuner, 1963), with settled agriculture leading to meat becoming an essential part of their diet. Worldwide meat production has tripled over the last few decades and increased by 20% in just the last decade. Pork is the most widely eaten meat in the world, accounting for over 36% of the world meat intake, followed by poultry and beef, with about 35% and 22%, respectively (FAO, 2014).

4.2 HISTORY OF MEAT AND POULTRY PRODUCTS

Humans, being omnivorous, have consumed animals and plants as foods throughout history. Humans ate raw meat after hunting animals. Rearing of livestock by humans provided a structural support to the economy as an important vocation for the human
population, next only to crop raising. It was in the 1490s, when Columbus brought Spanish longhorns to the West Indies, that the market for meat started to evolve. Because of positive socioeconomic factors, such as changing eating habits, urbanization, and increasing consciousness about a protein-rich diet and health foods, there has been an increase in the demand for meat, and the sector has gained importance in terms of contributions to income, employment, and foreign exchange earnings. Meanwhile, industrial countries are consuming larger amounts of meat, nearly double the quantity in developing countries. The strong growth in meat production is attributed to the rise of industrial animal agriculture, or factory farming. It was in the 1950s when the canning industry was booming, enabling highly perishable foods, including meat, to be shipped and marketed to distant locations (Kristensen, Stoier, Wurtz, & Hinrichsen, 2014).

Ethnic and traditional meat and poultry products are huge and diverse in nature. South Asian countries, such as India, Pakistan, Bangladesh, Nepal, and Sri Lanka, have had meat and poultry products that percolated down through history and metamorphosed into spicy ethnic meat products (Bhandare, 2014). The meat products common to these regions include kabab, tikka, biryani, curry, meat pickle, and dry salted meat. Japanese cuisine has historically been influenced by China and Korea. However, such influences have mingled with unique Japanese natural resources and culture, contributing to a well-established Japanese cuisine. Japan has a relatively short history of developing meat-based foods in its tradition, compared to other neighboring Asian countries (Kim and Jang, 2014).

There are more than 100 different types of traditional Chinese meat products in mainland China. Many of these products can also be found in Southeast Asian countries and in metropolitan cities where there is a sizeable ethnic Chinese population. These products can readily be produced in home kitchens as well as in restaurant kitchens. Some of the traditional Chinese meat products are now manufactured in meat-processing plants using the latest meat processing technology and machinery while maintaining the characteristics of Chinese dietary customs and product formulations; examples include Chinese-style pork sausages and Jinhua ham. Traditional and ethnic meat products in the Islamic Middle East use beef, buffalo, mutton, lamb, goat, camel, poultry, and horse meat. Seasoned meat is grilled as kebabs. Sausages and fresh and cooked (nakanek) or uncooked (smoked or heavily smoked, fermented, and seasoned) salamis and pastrami are common products. A sweet dish uses the lungs, spleen, large intestine, esophagus, and rice fried (membar) in oil (Egypt, Syria, and Turkey). Minced meat (masmat) includes lower legs (kawareh), head meat, stomach, eyes (gawaher), and tail (akkawi). In the Middle East, there are traditional specialties such as blanched buffalo or cattle feet (Egypt and Syria), kobeba using beef and wheat (Lebanon and Syria), and hawawshy bread using minced meat and wheat dough (Egypt; El-Magoli and Abd-Allah, 2014). In South America, before the arrival of the Spanish in 1492, people in the Americas relied on their autochthonous fauna as a meat source; the most relevant of these were the alpaca (Lama pacos),
capybara (*Hydrochoerus hydrochaeris*), guanaco (*Lama guanicoe*), llama (*Lama glama*), nutria (*Myocastor coypus*), collared peccary (*Tayassu tajacu*), greater rhea (*Rhea americana*), lesser rhea (*Rhea pennata*), yacare (*Caiman crocodilus yacare*), tegu lizard (*Tupinambis merianae*), and green iguana (*Iguana iguana*) (Gonzalez-Schnake and Nova, 2014). After the arrival of the conquistador Europeans, domestic livestock were gradually introduced, and these breeds are the ones that currently dominate the local market and make South America the largest meat producer in the world. As well as the introduction of new domestic animals for human consumption, several meat products were brought from Spain, Italy, and Portugal.

Other ethnic meat products are specific to the following countries, cities, and regions: North America (e.g., pemmican, whole-muscle jerky, restructured jerky, summer sausage, Lebanon bologna, scrapple, hamburger, barbecue, hot wings, chili con carne); Germany (e.g., Schwarzwälder Schinken, Ammerländer Schinken, Holsteiner Katenschinken, Westfälischer Knochenschinken, Badisches Schäufele, Frankfurter [frankfurters], Wiener, Knacker [knockwurst], Bayerischer Leberkäse [meat loaf], Halberstädter Würstchen, Münchner Weißwurst, Pfälzer Saumagen); France (*blanquette de veau* [veal blanquette], charcuterie [delicatessen], dry sausages [*saucisson et saucisse sèche*], cooked ham [*jambon de Paris*] and dry-cured ham [*jambon sec*], and pâtés, terrines, and rillettes); and Poland (*Jalowcowa, Kabanosy, Krakowska sucha, Mysliwska*).

### 4.3 PUBLIC HEALTH RISKS

Foodborne illness has been a serious public concern and continues to be recognized as a major human health problem. Because meat is a rich source of nutrients, it provides a suitable environment for the growth and propagation of spoilage and foodborne pathogens. Meat spoilage can occur by infection of the living animal by spoilage microorganisms (endogenous disease) or by contamination of the meat postmortem (exogenous disease), with the latter being encountered more often. Owing to its diverse nutrient composition, meat is an ideal environment for the development of various types of microorganisms. The contamination of carcasses and raw products by microorganisms is practically unavoidable. Adequate preservation processes have been designed to ensure the safety and quality of raw and processed meat products. However, traditional meat-based foods are linked to the emergence of new foodborne diseases that challenge the safety of traditional preservation methods of meat.

Chicken and meat are staple foods in various cultures and are commonly consumed in many countries, consequently contributing to a high incidence of salmonellosis. Traditionally, known meat products have been reported to have a higher bacterial count, because no important hygienic rules are followed, and these foods have no regulatory requirements in many parts of the world. Despite improved hygienic conditions in meat processing, concern about meat and meat products as vehicles of foodborne pathogens
is increasing. Major outbreaks of foodborne diseases have been associated with the consumption of contaminated meat. Maintaining a high level of hygiene and a low bacteria count under all conditions, in combination with low storage temperatures, are the two major barriers against the spoilage of fresh meat. Authorities in most of the developed countries have established strict regulatory measures for improving hygiene in the meat industry. The development and use of hazard analysis and critical control point programs and sanitation-related standard operating procedures have increased safety and decreased outbreaks by meat and meat products.

4.4 TRADITIONAL METHODS OF MEAT AND POULTRY PRESERVATION

Meat is one of the most highly perishable foods and becomes unfit for human consumption, and possibly dangerous to health, through microbial growth and breakdown by endogenous enzymes. A number of processes have long been used for preserving the keeping quality of meat, and well-developed processing methods are now available. Traditional methods of meat preservation that have been used for years involve cooking, drying, salting, curing, pickling, and fermentation. Although the concepts involved in traditional preservation methods were not known earlier, the main idea was to decrease water activity to levels low enough to inhibit the growth of spoilage microorganisms.

4.4.1 Cooking

Cooking is one of the primary and oldest traditions for preparing most meat- and poultry-based ethnic Asian curries. Meat chunks or minced meat balls are cooked in water with spices, salt, and chilies to prepare delicious ethnic meat and poultry products. After 30–60 min of boiling, combined with frying, the meat texture softens, and the soup or curry thickens and an appropriate flavor is developed. The product is served fresh or is further preserved for long-distance distribution.

4.4.2 Canning

Canned meat products include whole muscles, meat stews, luncheon meat, sausages, sauces with meat pieces, and paste products (Guerrero-Legarreta, 2014). Meat canning essentially includes three main operations – can filling, exhaustion, and heat treatment. Heat penetration is affected by the solid-to-liquid ratio as well as the distribution of the solid within the can. Solid materials packed loosely are heated faster than closely packed material. In general, 30% of the can volume must be a liquid (brine or sauce) to allow good heat transfer. When pastes are put into the can, it is important to ensure the absence of air bubbles, because heat transfer is less efficient in air and may create sterilization problems. Headspace, approximately 0.5% of the total can volume, must also be taken into consideration in thermal calculations.
Exhaustion is carried out by evacuation of air from the headspace and the bulk of the food. This is necessary to achieve good heat penetration and desired sterilization temperature. Air exhaustion also reduces the risk of promoting the growth of aerobes, particularly if the product is pasteurized, as are some luncheon meats. Exhaustion is generally carried out by vapor injection or by conveying the cans on a belt into an exhaustion chamber or tunnel in which they are heated at 85–95°C, removing 90% or more of the air in the headspace. In both cases, the cans are then immediately sealed. When the cans are cooled, a partial vacuum is produced by condensation of the water vapor. Several meat and poultry products are canned to achieve sterility and meet regulatory standards, and canning is often for delivery to the armed forces in distant places where refrigeration of the product is not possible.

4.4.2.1 Drying meat

Drying is an ancient food preservation technique, in which water present in meat muscle is evaporated or sublimated by diffusion from internal surfaces. Due to significant reduction in water activity, the viability of microorganisms decreases significantly. Drying has a pronounced effect on the textural and aromatic properties of meat; hence, the drying conditions must be properly designed to attain maximum quality retention. Rapid removal of moisture from meat products will result in surface hardening, whereas slow removal of moisture will increase the possibility of the growth of undesirable microorganisms. Fresh raw meat can be dried a few hours after slaughtering, but refrigerated and frozen meat must be properly thawed before processing. Drying can be used as the only method for the production of shelf-stable meat products, or it may be combined with other methods, such as smoking, salting, seasoning, and curing.

4.4.2.2 Curing

Curing is a meat modification method that affects preservation, flavor, color, and tenderness due to added curing agents. Curing treatments were practiced as a means of preserving meat before the days of refrigeration, and curing dates back to 1500 BC. In some traditional practices, curing is still used as a preservation process. Curing is based on an empiric observation that salting could preserve meat without refrigeration. The use of salt is one of the oldest methods of preserving meat because it inhibits the growth of most spoilage microorganisms at a concentration greater than 4% in the aqueous phase. The main ingredients used for curing or pickling are sodium chloride, sodium nitrate or nitrite, sugar, and spices. Sodium chloride is used as a mild preservative and adds flavor, sugar helps stabilize color and adds flavor, and nitrates and nitrites are helpful for the development of unique flavor in cured meats, act as preservatives, and have antibotulinum activity. In most cured meats, the salt concentration is between 2.5% and 5%. Early curing procedures were lengthy, and recent developments have led to a reduction in the
time required. Instead of simply immersing the meat in brine, it is first injected with the curing solution, and the process can be completed in 1–2 weeks.

Consumer demands toward minimally processed and convenient to use foods has led to a preference for cured and smoked foods with lower salt, lower nitrate, and high moisture levels. These factors, however, have had a tremendous impact on the safety of cured meats. In recent years, sodium nitrate and nitrite have received considerable attention with respect to their safety in this application. The addition of sodium ascorbate accelerates the curing process owing to its reducing capacity, allowing smaller amounts of nitrites to be used. However, it will be difficult to eliminate the use of nitrates and nitrites completely because there is no known substitute available for the curing of meats.

4.4.2.3 Smoking
Slow combustion of sawdust derived from hardwoods produces smoke, which inhibits microbial growth, retards oxidation of fats, and imparts flavor to cured meats (Lawrie & Ledward, 2007). Meat has been treated with smoke from the earliest days, traditionally over a wood fire and more recently by producing smoke from wood sawdust in a generator and conducting the smoke over the meat. The substances deposited on the meat contribute to its flavor and appearance, but the preservative effect is mild when ordinary light smoking is carried out. Intensive smoking prolongs shelf life by a heavy deposition of preservatives and by a drying effect, but has a detrimental effect on the flavor of the final product. As such, preservation by smoking is regarded as an emergency measure and should be carried out only when other methods cannot be used.

4.4.2.4 Fermentation
The production of fermented meat products goes back thousands of years because it was quickly discovered that shelf-stable meat products could be produced by adding salt to meat and subsequently dried or fermented. Fermentation involves complex microbial ecosystems that combine bacteria, yeasts, and molds. Fermented meat products such as salami, ham, and sausages are very popular foods around the world, where different cultures contribute to their texture, flavor, and safety. The most important microorganisms responsible for product transformation during fermentation are lactic acid bacteria (mainly Lactobacillus spp.) and coagulase-negative cocci (Staphylococcus and Kocuria spp.), which seem to have the capacity to survive during fermentation. The technology behind the production of fermented meats and their safety is discussed in detail later in this book.

4.5 EPIDEMIOLOGY
There are several routes of the development of biologic hazards to meat and poultry products, primarily due to favorable growth conditions. It is essential to control such hazards because the international trade in meat means that outbreaks can rapidly affect
many countries. Depending on the biology and epidemiology of the hazard, they can cause subclinical or clinical disease in livestock and subsequent losses due to suboptimal growth or production. These hazards can also reduce the suitability of meat for use in certain products during processing or can lead to cross-contamination as a consequence of hygiene failure. Perhaps most important, meat-borne hazards can cause illness in consumers, ranging from subclinical infection to severe disease and even death. Pathways of infection might be complex if other foods are contaminated and result in indirect infection. Major biological hazards with serious epidemiologic concerns for meat and poultry products are listed in Table 4.1 and discussed further in this section.

Table 4.1 Genera of bacteria and yeasts most frequently found on meats and poultry

<table>
<thead>
<tr>
<th>Genus</th>
<th>Fresh meat</th>
<th>Processed meat</th>
<th>VP/MAP</th>
<th>Poultry</th>
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<td><em>Bacteria</em></td>
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<td>Chromobacterium</td>
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<td>Clostridium</td>
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<td>Neisseria</td>
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4.5.1 Campylobacter

Campylobacter species are associated with human gastroenteritis in developed and developing countries. Campylobacteriosis in humans is caused by thermotolerant Campylobacter spp., and the infective dose of these bacteria is generally quite low (less than 100 viable organisms). Campylobacter jejuni, followed by Campylobacter coli and Campylobacter lari, are the main species associated with human infection, but other Campylobacter species are reported to cause human infection. C. jejuni and C. coli in humans cause acute inflammatory enteritis following an incubation period of approximately 3 days (ranging from 18 h to 8 days). This leads to cramping and profuse diarrhea accompanied by fever, headache, dizziness, and/or myalgia. In rare cases, infection by Campylobacter spp., may lead to Guillain–Barré syndrome and Miller–Fisher syndrome, which are reportedly common paralytic diseases in the United States. This pathogen is present in many farm animals, and poultry is very susceptible to colonization with high numbers of Campylobacter.
The average incidence of *Campylobacter* spp. in animals and foods, according to different studies, were approximately 33% for live chickens, 53% for chicken meat, 56% for turkey meat, 32% for geese, ducks, and other fowl, 45% for cattle, 6% for beef cuts, and 27% for pork and pork meat. Campylobacteriosis has remained the most frequently reported zoonotic disease in humans in the European Union (EU) since 2005, as reported by the European Food Safety Authority. Overall, 212,064 confirmed cases of this disease were reported in 2010, which represents an increase of 6.7% compared to 2009. The overall notification rate of human campylobacteriosis was 48.6/100,000 population. As in previous years, children under the age of 5 had the highest notification rate (126.8/100,000 population). However, the case fatality rate for human campylobacteriosis was low (0.22%). According to the last report of the US Center for Disease Control and Prevention (CDC), it was estimated that 6,365 cases of acute gastroenteritis caused by campylobacteriosis infection occurred in 2010. The overall notification rate of human campylobacteriosis in 2010 was 13.6/100,000 population. Campylobacteriosis is alarming in developing countries, mainly due to large unhygienic processing conditions and often remains unreported due to a poor assessment infrastructure.

### 4.5.2 *Salmonella* spp.

*Salmonella* belongs to the species of Enterobacteriaceae family that are divided into two different groups, *Salmonella enterica* and *Salmonella bongori*. *S. enterica* subspecies are *enterica*, *salamae*, *arizonae*, *diarizonae*, *houtenae*, and *indica*. Serotype subgrouping divides *Salmonella* into serotypes developed by Kaufmann and White – for example, *S. enterica* subsp. *enterica* serovar Derby (or *Salmonella* Derby). There are more than 2600 serovars of zoonotic *Salmonella*, and the prevalence of the different serovars are reported to change over time.

*Salmonella* has long been recognized as an important zoonotic pathogen of economic significance in animals and humans. Salmonellosis is usually characterized by the acute onset of fever, abdominal pain, nausea, diarrhea, and sometimes vomiting after an incubation period of 12–36 h. Symptoms are often mild and most infections are self-limiting, lasting for a few days. However, in some patients, the infection can be more serious and the associated dehydration can be life-threatening. When *Salmonella* causes systemic infection, such as septicemia, effective antimicrobials are essential for treatment. Mortality is usually low, and less than 1% of reported *Salmonella* cases have been fatal. According to the European Food Safety Authority, in 2010, a total of 99,020 confirmed cases of human salmonellosis were reported in the EU. This represents a decrease of 8.8% over the previous year. The EU notification rate for confirmed cases was 21.5 cases/100,000 population. The case fatality rate of human salmonellosis in 2010 was 0.13%. Detection of *Salmonella* was reported in a wide range of foodstuffs, but most figures were from various types of meat and meat products. The highest proportions
of Salmonella-positive units were reported for fresh broiler meat and fresh turkey meat, at average levels of 4.8% and 9.0%, respectively. The overall notification rate of human infection due to Salmonella in 2010 was 17.6/100,000 population, with a case fatality rate of 0.4%. Salmonellosis is more prevalent in Asia and Africa and causes many deaths and outbreaks; quite often, cases go unreported due to lack of testing procedures and regulation enforcement. In developing countries, washing meat with fresh water is also reported to be a route of contamination; the meat becomes contaminated due to the direct discharge of waste into water bodies.

4.5.3 Clostridium perfringens

Clostridium perfringens is an important pathogen of the human gastrointestinal (GI) tract that may cause food poisoning, antibiotic–associated diarrhea, and sporadic diarrhea. The most important toxin made by this bacterium when in the human GI tract is the C. perfringens enterotoxin. Although ubiquitous in the environment, only a small subpopulation of C. perfringens (usually less than 5%) is pathogenic. The number of C. perfringens cells (cpe-positive and cpe-negative strains) present in most nonoutbreak food samples is generally lower than 10 CFU. C. perfringens foodborne disease is third in incidence among foodborne illnesses in the United States, causing about 965,958 cases annually. Beef, poultry, gravies, and dried or precooked foods are common sources of C. perfringens infections. Deaths are uncommon, but might occur in older adults, debilitated individuals, or people otherwise predisposed to disease. The key event for the development of disease is the mishandling of foods, from preparation to consumption, which can occur especially in poultry and beef. Failure to refrigerate after cooking can provide an opportunity for the germination of spores and multiplication of vegetative cells.

4.5.4 Escherichia coli

Since the mid-1940s, evidence has accumulated that certain Escherichia coli strains cause diarrhea, particularly in infants, and they were designated as enteropathogenic E. coli. However, current evidence indicates that pathogenic strains of E. coli are of more than one type. They are subdivided into four groups and have been subdivided into six groups, including the four discussed here, together with the enteroaggregative E. coli (EAggEC) and diffuse-adhering E. coli (DAEC). The pathogen is probably present in the intestines of animals, particularly in dairy cattle, without producing symptoms. It may be present in any food of animal origin, especially ground beef; those infected were found to have consumed improperly cooked contaminated hamburgers. In addition to ground beef, other foods, such as raw milk, apple cider, some fruits, uncooked sausages, sprouts, and salad have been implicated. Investigation has revealed the presence of E. coli O157:H7 in many different types of food of animal origin, such as ground beef, pork, poultry, lamb, and raw milk, in low percentages. The organism was isolated in low frequency from dairy cows as well as calves and chickens.
4.5.5 *Listeria monocytogenes*

The bacterial genus *Listeria* currently comprises eight species, but human cases of listeriosis are almost exclusively caused by *Listeria monocytogenes*. The risk of contracting listeriosis is high for immunocompromised persons, older adults, pregnant women, and neonates. Thirteen serotypes of *L. monocytogenes* have been identified, but only three serotypes (1/2a, 1/2b, and 4b) are associated with most outbreaks or sporadic cases of listeriosis. *Listeria* spp. are organisms that are widely distributed in the environment, especially in plant matter and soil. The principal reservoirs of *Listeria* are soil, forage, and water; other reservoirs include infected domestic and wild animals. The main route of transmission to humans and animals is believed to be through consumption of contaminated food or feed. Cooking at temperatures higher than 65°C destroys *Listeria*, but the bacteria are known to survive under adverse conditions, forming biofilms and multiplying at temperatures as low as 4°C. Cross-contamination of the product can still occur after the killing stops, and *L. monocytogenes* occurrence in ready to eat foods with a relatively long shelf life is of particular concern. *L. monocytogenes* infection might result in a wide range of clinical symptoms. Infection can be noninvasive (gastroenteritis, fever) or invasive. The latter can lead to influenza-like symptoms, meningitis, central nervous system damage and, in pregnant women, fetal infection and/or abortion. Incubation times for invasive infection can be up to 90 days, increasing the difficulty of attributing a particular food vehicle to cases.

*L. monocytogenes* has been recovered from many different foods and, conversely, a variety of different food items such as raw and processed meats, soft cheese, raw milk, hot dogs, seafood, and fresh vegetables and fruits have been linked to sporadic cases and outbreaks of listeriosis. Pork meat and processed pork products, such as delicatessen meats, have been implicated in *Listeria* outbreaks in European countries during the past decade. *L. monocytogenes* is of particular concern in raw, undercooked, or ready to eat foodstuffs. Listeriosis cases have been reported mainly in the Northern hemisphere, with very few reports in the Southern hemisphere. A total of 1,601 confirmed cases of listeriosis were reported in 2010 by the European Union. As in previous years, older persons were especially affected by the disease, with 60.2% of cases occurring in individuals over the age of 65. Overall, a high case fatality rate of 17.0% was recorded among those cases for which information was available (in 2009, 16.6%). The EU notification rate was 0.35/100,000 population in 2010, which was slightly lower than in 2009 (0.4/100,000 population). The US Centers for Disease Control and Prevention estimated that 125 cases of listeriosis occurred in 2010. The overall notification rate of human listeriosis in 2010 was 0.3/100,000 population. However, the case fatality rate was approximately 12.8%, the highest among all foodborne zoonoses.

4.5.6 *Yersinia enterocolitica*

*Yersinia enterocolitica* is an important foodborne enteropathogen known for causing the disease termed *yersiniosis*. Clinical manifestations of yersiniosis range from mild
Regulating Safety of Traditional and Ethnic Foods

gastroenteritis to invasive syndromes like terminal ileitis and mesenteric lymphadenitis. Yersiniosis occurs mostly in young children with symptoms of mild gastroenteritis. However, in older persons and in patients with underlying conditions (e.g., iron overload, cirrhosis, diabetes, cancer), systemic forms of the disease are often observed. Symptoms typically develop 4–7 days after exposure and last an average of 1–3 weeks. In older children and adults, right-sided abdominal pain and fever might be the predominant symptoms and can often be confused with appendicitis. Other symptoms such as rash, joint pain, and/or bacteremia can occur. Infection is most often acquired by eating contaminated food, particularly raw or undercooked pork meat. The bacterium is able to grow below 4°C, making contaminated refrigerated food a probable source of infection. Even though this species comprises 6 biotypes and nearly 50 serotypes, the most frequently implicated serotype in human disease worldwide is O:3, with almost all strains belonging to biotype 4. Swine are the main reservoir of pathogenic Y. enterocolitica strains, harboring them in tonsils and in the oral cavity. The most common route of transmission of yersiniosis is through contaminated water and foods.

4.5.7 Emerging pathogens

Other foodborne pathogens are considered to be emerging because they are new microorganisms or because the role of food in their transmission has been recognized only recently.

Since the description of the genus Enterococcus in the 1980s, many taxonomic investigations have resulted in the assignment of about 30 species; the two most prominent representatives are Enterococcus faecium and Enterococcus faecalis. Several species of enterococci can be easily distinguished from other cocci by their ability to grow at 10 and 45°C in 6.5% NaCl, in the presence of 40% bile, and at a pH of 9.6. The enterococci are important in environmental, food, and clinical microbiology because they can be found in the intestines of food animals and can contaminate the meat during slaughtering. In raw meat products (beef and pork cuts), E. faecalis and E. faecium are the most predominant species isolated, with mean counts ranging from $10^4$ to $10^8$ CFU/100 cm².

Enterococcus can not only contaminate raw meats, but can also be associated with processed meats. Cooking of processed meats might confer a selective advantage on enterococci because these bacteria are known to be among the most thermotolerant of the nonsporulating bacteria. Enterococcus are typical opportunistic pathogens and can cause infection in patients who have severe underlying disease or are immunocompromised. They can cause bacteremia, endocarditis, and urinary tract and other infections. The question of whether food strains possess an intrinsic lower pathogenic potential than clinical isolates has still not been fully determined, and additional data are needed.

Another emerging foodborne pathogen is the species Clostridium difficile, an anaerobic, spore-forming bacterium that can produce toxin A or B on colonization of the gut. Patients at risk for C. difficile infection (CDI) subsequently develop diarrhea or, in
severe cases, pseudomembranous colitis. Traditionally, older and hospitalized patients who had been under antibiotic therapy were considered to be the most vulnerable to CDI. Because food animals can be colonized by *C. difficile*, and the bacteria has been isolated from retail meats, some researchers speculate that *C. difficile* is a food-associated organism, and consumption of contaminated meat could be responsible for an increased incidence of community-associated CDI.

### 4.6 LOCAL AND GLOBAL REGULATORY STATUS

Regulations on the meat and poultry products vary from state to state and are strictly enforced in most of the developed countries. In Europe, the European Commission acts as the competent authority on behalf of the member states to ensure that there is compliance with these import rules. The European Commission is the sole negotiating partner for all non-EU countries in questions related to import conditions for processed meat. The eligibility criteria are as follows:

- Exporting third countries must have a competent authority that is in charge of the inspection and certification of veterinary and general hygiene conditions.
- The country or region of origin must fulfill the relevant animal health standards of the EU.
- National authorities must also guarantee that the hygiene and public health requirements are met and that a monitoring system is in place to verify compliance with the maximum permitted levels of residues of veterinary medicines, pesticides, and contaminants.
- Imports are only authorized from approved establishments (e.g., slaughterhouses, cold stores, processing plants) for which the national authorities have submitted guarantees.

Imports of meat or meat products must enter the EU via an approved border inspection post under the authority of an official veterinarian. Each consignment is subject to a systematic documentary check, identity check and, as appropriate, a physical check, which can include laboratory analysis. The frequency of physical checks depends on the risk profile of the product and also on the results of previous checks. Consignments that are found not to be compliant with community (EU) legislation shall be destroyed or, under certain conditions, returned to sender within 60 days. If processed meat consignments have been tested and rejected at the external borders of the EU (and the European Economic Area) and a health risk has been found, a notification is sent to all European Economic Area border posts to reinforce controls and ensure that the rejected product does not re-enter the EU through another border post. The US Food and Drug Administration, has a similar approach to check on meat and poultry products. The Food Safety and Standards Authority of India has been designated to check meat and poultry products, but traditional meat and meat products, which are not licensed
by the government, mainly remain unchecked in the market. The trend is similar in other countries, in which ethnic meat and poultry products, sometimes called “street foods,” mostly remain unchecked. There is a need to develop platform tests for the risk assessment of street food. This will ensure strict control on street food and prevent large number of outbreaks in developing countries.

4.7 FUTURE TRENDS AND EXPECTATIONS

The food industry in developing countries such as China, India, South Africa, Brazil, and the Middle East are growing at a fast rate. The demand for processed traditional or ethnic foods is also increasing due to an increase in gross domestic product and more women in the workforce. Mechanization and/or large-scale processing of traditional meat and poultry products in these countries will generate many jobs and at the same time ensure that safe products are delivered to consumers. This will also increase the export of traditional meat and poultry products from distant places such as Asia to the European Union and American continents, as in the case of sushi from Japan. Food plant machinery has to be developed to meet the specific needs of traditional meat and poultry production so that the automation can reduce contamination risks.

4.8 CONCLUSIONS

Traditional and ethnic meat and poultry products receive much attention in their specific regions. A large number of foodborne outbreaks occur, especially during the summer, when ambient temperature conditions support the growth of most spoilage and pathogenic microorganisms. The quality of most street foods remains unchecked in many countries. The development of rapid detection or platform tests would help the regulating authorities keep a proper check on street foods and would improve hygiene and safety during handling, processing, and distribution to consumers. Ethnic meat and poultry products can be processed on a large scale and packed in appropriate packaging for distribution through supermarkets. This will require the development of appropriate automation with hygienically designed machines to avoid human contact, so that safe food is delivered to consumers.

REFERENCES


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